Optotune solutions for microscopy

Introduction

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Product portfolio
Our solutions to enhance your microscopes

Focus tunable lenses
- Fast autofocus
- Fast detection
- Image stacking

Laser speckle reducers
- Homogeneous laser illumination field
- Noiseless
- Compact

Beam steering devices
- Sole reflection
- Wide angular range
- Compact
**Product portfolio**
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**Current situation**
How do we move from 2D to 3D

**Goals**
- Imaging of 3D cell cultures
- Imaging of whole embryos
- In-vivo imaging

**Limitations**
- Depth of field (DOF)
- Mechanical vibrations
- Focusing speed

**Solution**
- 3D microscope
## Current solutions
To focus along Z-axis

<table>
<thead>
<tr>
<th></th>
<th>Motorized Z</th>
<th>Piezo Z</th>
<th>Focus Tunable Lens</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Motorized Z" /></td>
<td><img src="image2.png" alt="Piezo Z" /></td>
<td><img src="image3.png" alt="Focus Tunable Lens" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>Motorized Z</th>
<th>Piezo Z</th>
<th>Focus Tunable Lens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price</strong></td>
<td>$$</td>
<td>$$$</td>
<td>$</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>+</td>
<td>+++</td>
<td>+++ (100Hz)</td>
</tr>
<tr>
<td><strong>Travel Range</strong></td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Compactness</strong></td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Vibrations</strong></td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Thermal Drift</strong></td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
</tbody>
</table>
**Working principle**
Membrane with fluid and actuator

- **Human eye:** Ciliary muscle actuates the lens curvature
- **Optotune lens:** Electromagnetic actuator controls the lens curvature

See also: [https://www.optotune.com/tunable-lenses](https://www.optotune.com/tunable-lenses)
## Our product range
Liquid lenses for microscopy applications

<table>
<thead>
<tr>
<th></th>
<th>EL-3-10-TC</th>
<th>EL-10-30-TC</th>
<th>EL-10-30-C(i)</th>
<th>EL-16-40TC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focal power range</strong></td>
<td>-13 ... +13 dpt</td>
<td>8 ... 22 dpt</td>
<td>-1.5 ... +3.5 dpt</td>
<td>-2 ... +3 dpt</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+5 ... +10 dpt</td>
<td>-10 ... +10 dpt</td>
</tr>
<tr>
<td><strong>Clear aperture</strong></td>
<td>3mm</td>
<td>10mm</td>
<td>10mm</td>
<td>16mm</td>
</tr>
<tr>
<td><strong>Outer diameter</strong></td>
<td>10mm</td>
<td>30mm</td>
<td>30mm</td>
<td>40mm</td>
</tr>
<tr>
<td><strong>Response time</strong>*</td>
<td>1 / 3 ms</td>
<td>4 / 9 / 20 ms</td>
<td>2.5 / 6 / 15 ms</td>
<td>5 / 12 / 25 ms</td>
</tr>
<tr>
<td><strong>Wavefront quality RMS @525nm</strong></td>
<td>&lt;0.07 λ</td>
<td>&lt;0.15 λ</td>
<td>&lt;0.1 λ</td>
<td>&lt;0.15 λ</td>
</tr>
<tr>
<td><strong>Absolute focal power accuracy (typical)</strong></td>
<td>N/A</td>
<td>&lt; 0.1 dpt</td>
<td>&lt; 0.1 dpt</td>
<td>&lt; 0.05 dpt</td>
</tr>
<tr>
<td><strong>Typical use case</strong></td>
<td>Machine Vision</td>
<td>Microscopy</td>
<td>Small and mid size sensors</td>
<td>Large sensors</td>
</tr>
</tbody>
</table>

* 10-90% of step / settling time of a controlled step / settling time of rectangular step

** class 1 specification
Microscopy configurations
How ETL impacts on the image magnification

<table>
<thead>
<tr>
<th>Z-range with 5D lens</th>
<th>Mag change*</th>
</tr>
</thead>
<tbody>
<tr>
<td>10x 2560 μm</td>
<td>7.5%</td>
</tr>
<tr>
<td>20x 640 μm</td>
<td>12.2%</td>
</tr>
<tr>
<td>40x 160 μm</td>
<td>23.7%</td>
</tr>
</tbody>
</table>

* Magnification changes are linear, it is possible to compensate it via software

Telecentric

<table>
<thead>
<tr>
<th>Z-range with 5D lens</th>
<th>Mag change</th>
</tr>
</thead>
<tbody>
<tr>
<td>10x 1000 μm</td>
<td>0%</td>
</tr>
<tr>
<td>20x 250 μm</td>
<td>0%</td>
</tr>
<tr>
<td>40x 60 μm</td>
<td>0%</td>
</tr>
</tbody>
</table>
Integrations
How ETL can become part of your systems

Digital inspection microscope

ETL Pos.
Tube lens
Zoom lens

Scientific microscope

ETL Pos.
(camera port)

ETL Pos.
(after objective)

ETL Pos.
(filter cube)

Parallel Infinity Space in Upright and Inverted Fluorescence Microscopes

Figure 7
Techniques overview
Different techniques, different applications

3D Microscopy

Wide-Field

Two-Photon

Digital Microscopy

Confocal

Light Sheet

Raman Spectroscopy
Integration: microscopy examples
Collaboration with our partners
Off the shelf Z-focus solutions
Based on Optotune EL-10-30 and EL-16-40

Life Sciences & Scientific Imaging
Microscopy Volume Imaging Solutions

Industries & Quality Control
3D Solutions For Microscopes And Automated Vision Systems

NeoScan
Fast Volume Scanning

ThunderScan
Ultra High Speed Scanning

ZeeScan
3D Add-On for microscopes

ZeeCam
3d microscope camera

Alpha³
Light Sheet Microscope
www.phaseview.com

InSight
Real Time 3D Acquisition

ZeeScope
3d measurement microscope

SmartScan
Motorless focus control
Four-dimensional visualization of zebrafish cardiovascular and vessel dynamics by a structured illumination microscope with electrically tunable lens

Speeded-Up Focus Control of Electrically Tunable Lens by Sparse Optimization

Large depth-of-field 3D shape measurement using an electrically tunable lens

Experimental validations of a tunable-lens-based visual demonstrator of multifocal corrections

Cell mechanotransduction with picowatt forces applied by optical tweezers

All-optical microscope autofocus based on an electrically tunable lens and a totally internally reflected 1R laser

Three-dimensional Two-photon Optogenetics and Imaging of Neural Circuits in vivo

NeuTracker—imaging neurobehavioral dynamics in freely behaving fish

High-speed dual-layer scanning photoacoustic microscopy using focus tunable lens modulation at resonant frequency

Quantifying three-dimensional rodent retina vascular development using optical tissue clearing and light-sheet microscopy

Three-dimensional multiple-particle tracking with nanometric precision over tunable axial ranges

Reduction of coherent artefacts in super-resolution fluorescence localisation microscopy

High-speed microscopy with an electrically tunable lens to image the dynamics of in vivo molecular complexes

Multi-depth photoacoustic microscopy with a focus tunable lens

Calcium transient prevalence across the dendritic arbour predicts place field properties

3d high- and superresolution imaging using single-objective SPIM

Fast imaging of live organisms with sculpted light sheets

A rapid image acquisition method for focus stacking in microscopy

Rapid quantitative phase imaging for partially coherent light microscopy

Investigation of diffraction-based measurement errors in optical testing of aspheric optics with digital micromirror devices
# Product portfolio

Our solutions to enhance your microscopes

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| - Fast autofocus  
- Focus detection  
- Image stacking | - Homogeneous laser illumination field  
- Noiseless  
- Compact |

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<td><img src="image3.png" alt="Beam steering devices" /></td>
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| - Sole reflection  
- Wide angular range  
- Compact |
Current situation
How do we improve laser illumination

Goals
- Even illumination field
- Better contrast
- Higher image quality

Limitations
- Noise
- Size
- Isotropic diffusers

Solution
- Laser speckle reducer
## Our product range
Laser speckle reducers for laser applications

<table>
<thead>
<tr>
<th></th>
<th>LSR-3005</th>
<th>LSR-4C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture</td>
<td>5 mm</td>
<td>18.5 mm</td>
</tr>
<tr>
<td>Size (L x H x D)</td>
<td>48x48x8.8 mm</td>
<td>40x40x3.8 mm</td>
</tr>
<tr>
<td>Standard diffuser angle</td>
<td>8.5°</td>
<td>8.5°</td>
</tr>
<tr>
<td>Oscillation frequency</td>
<td>300 Hz or 180 Hz</td>
<td>120 Hz +/- 10Hz</td>
</tr>
<tr>
<td>Oscillation amplitude</td>
<td>0.3 mm</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Electronics</td>
<td>Included</td>
<td>Included</td>
</tr>
<tr>
<td>Transmission</td>
<td>&gt; 93 (uncoated)</td>
<td>&gt; 98 (coated) &gt;94</td>
</tr>
<tr>
<td>Operating Life time</td>
<td>2.000 h</td>
<td>&gt; 40.000 h</td>
</tr>
</tbody>
</table>

No LSR – Contrast 0.27

LSR OFF – Contrast 0.26

LSR ON – Contrast 0.06
Application example
LSR boosts image quality in super-resolution fluorescence microscope


MRC5 cells stained with Alexa Fluor 647
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Current situation
How do we improve your scanning system

Goals
- Change the Light Plane
- AOI selection
- Laser scanning

Limitations
- Size
- Center of rotation not on mirror surface
- Double reflection

Solution
- 2D mirror
Our product range
2D Mirrors

<table>
<thead>
<tr>
<th></th>
<th>MR-15-30 standard</th>
<th>MR-10-30 2 resonant axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror size</td>
<td>15 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>Mechanical tilt – fast axis (half angle)</td>
<td>25°</td>
<td>12.5°</td>
</tr>
<tr>
<td>Full-scale bandwidth – fast axis</td>
<td>20 Hz</td>
<td>280 Hz</td>
</tr>
<tr>
<td>Mechanical tilt – slow axis (half angle)</td>
<td>25°</td>
<td>25°</td>
</tr>
<tr>
<td>Full-scale bandwidth – slow axis</td>
<td>20 Hz</td>
<td>20 Hz</td>
</tr>
<tr>
<td>Mech. Repeatability RMS typical</td>
<td>30-100 μrad</td>
<td>30-100 μrad (slow axis)</td>
</tr>
<tr>
<td>Footprint</td>
<td>30x14.5</td>
<td>30x14.5</td>
</tr>
<tr>
<td>Position feedback</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>